Update on Cavern Optimization

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LBNE/LBNF/ELBNF/etc. BNL Meeting

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Introduction

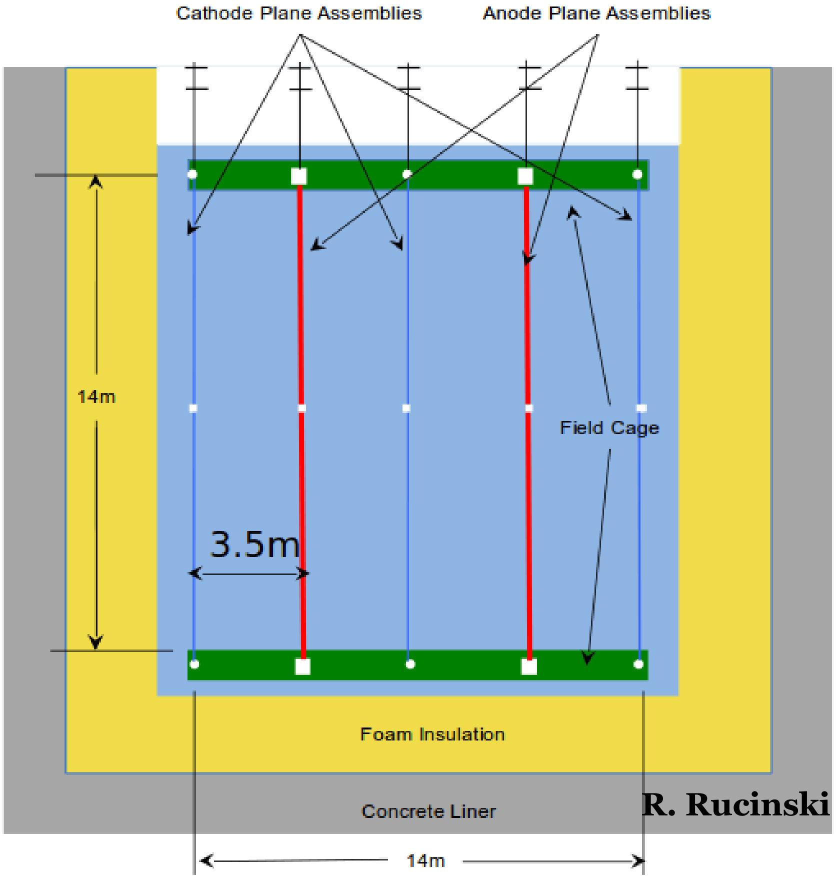
- Today's (brief) discussion on cavern optimization:
  - What has been done
    - Focus is lepton (electron/muon) containment
    - Main question: one or two caverns?
    - Outdated now as questions we are asking are changing...
  - Planned work
    - Include hadron containment
    - Main question: dimensions of 10-kt detectors?
    - In progress while juggling work from MicroBooNE

Previous Work

- Far detector cavern optimization: one or two caverns?
  - Many considerations (finances, engineering concerns, dead-time, etc.)
  - Must also consider **physics** case: do we lose sensitivity with two-cavern option?
- Begin by looking at lepton acceptance
  - **Electrons**: as function of energy containment fraction
  - **Muons**: as function of cut on maximum-allowed $\Delta p/p$ (from MCS)
- Take electron/muon $\{p, \cos[\Delta\theta(\nu,l)]\}$ distribution from FastMC
- Relative acceptance defined as fraction of events (vertex in fiducial volume) with projected shower/track length within active volume
  - Can eventually include APA gap considerations

Detectors Considered

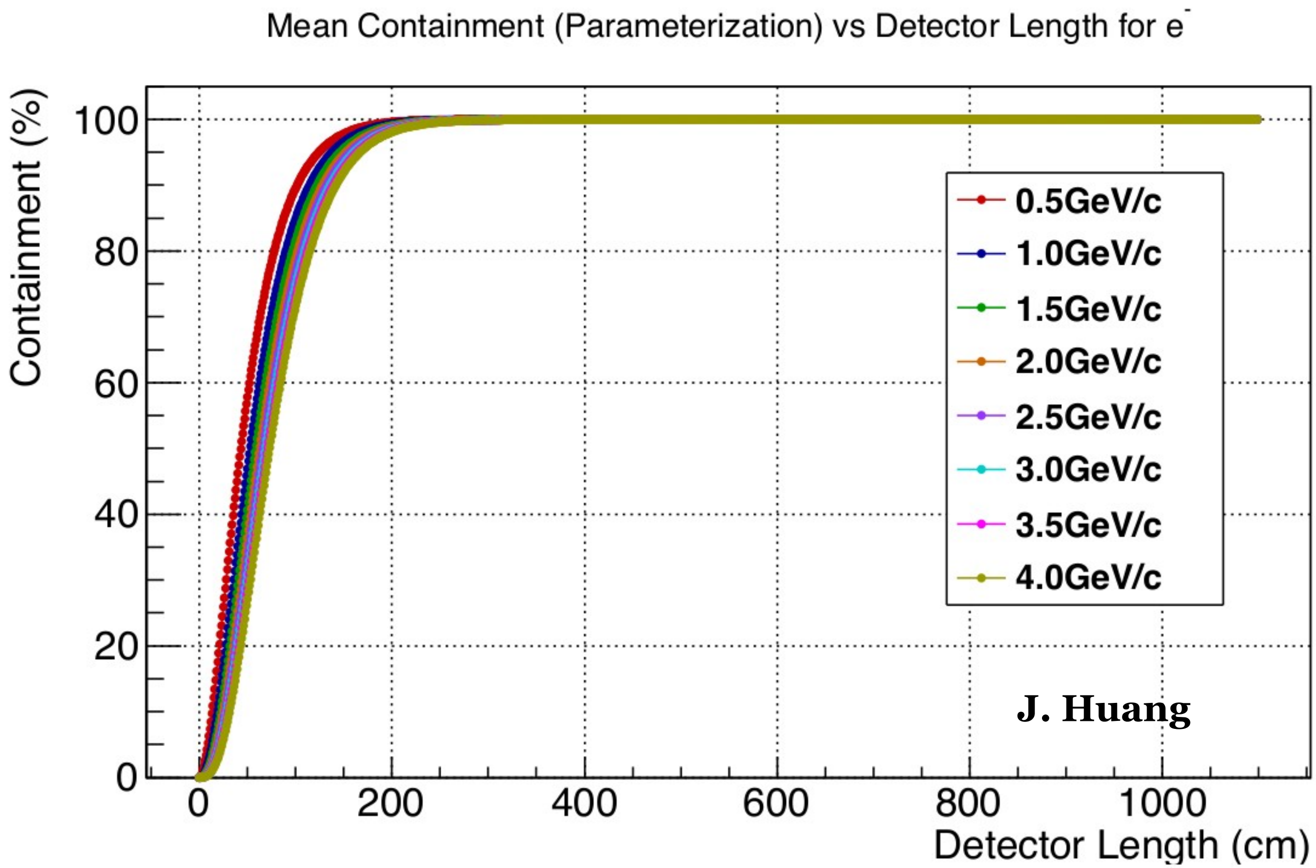
Example: 5-kton FD



In beam direction (into page): 25.6 m

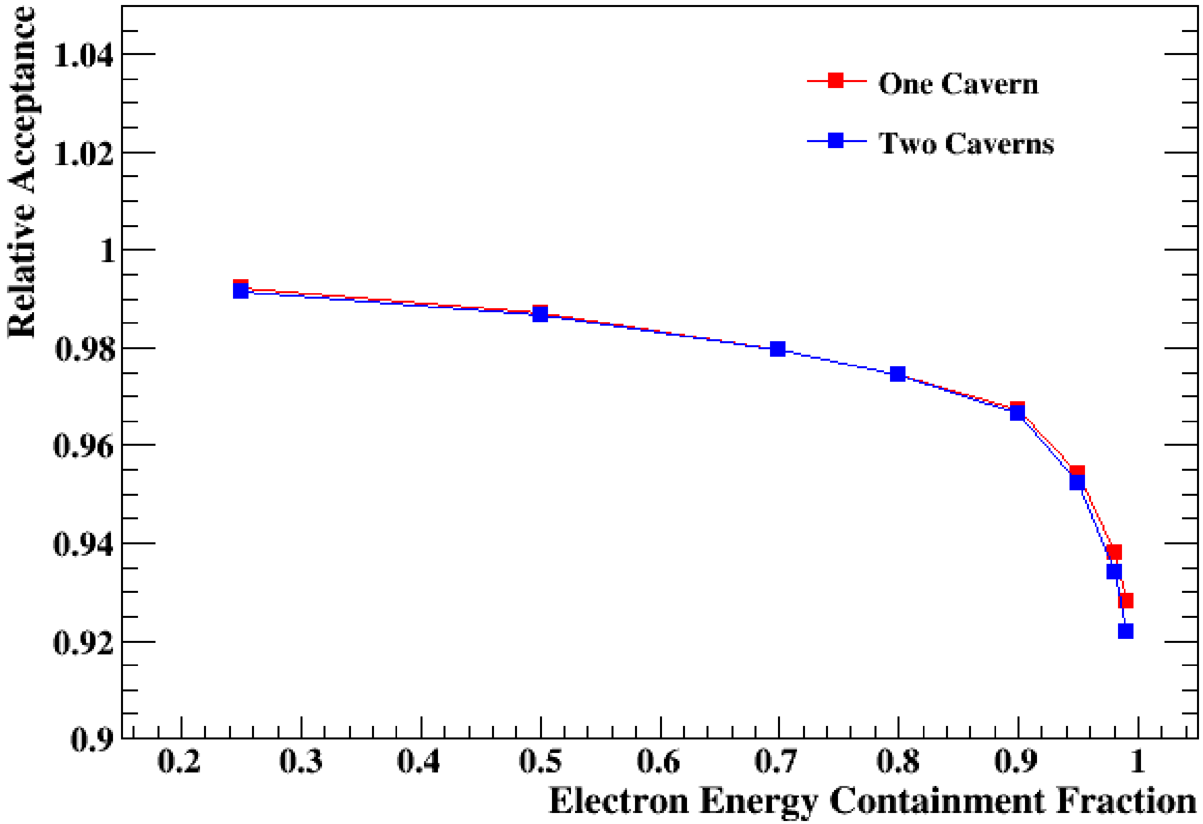
- Look at two cases:
  - **One cavern**: two 17-kton detectors
  - **Two caverns**: two 5-kton detectors + two 12-kton detectors
- Detector dimensions [m]:
  - 5-kton: {13.9, 14.0, 25.6}
  - 12-kton: {22.9, 14.0, 35.6}
  - 17-kton: {23.4, 14.0, 45.8}
- From Doc DB #3383-v45
  - Options 2+5 vs. 9
  - Somewhat outdated but still useful for these studies

Electron Shower Profile



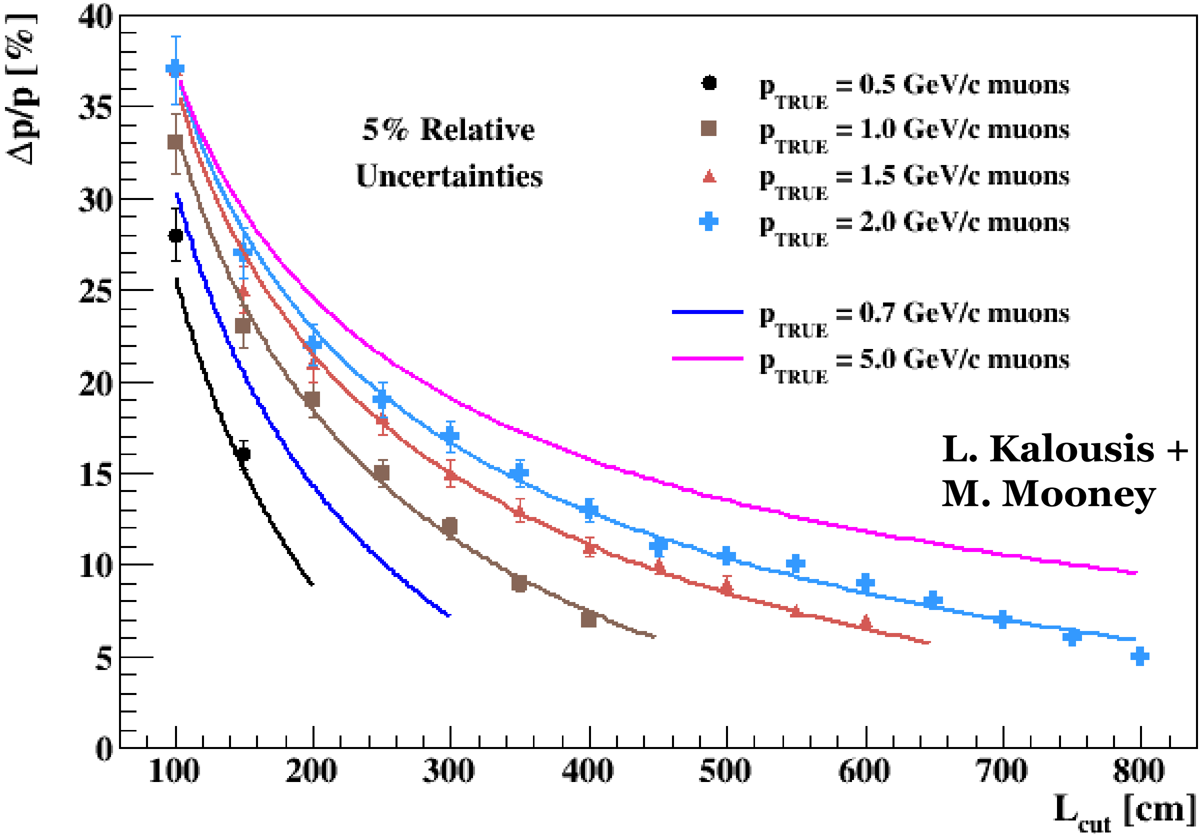
- Use previous study of shower containment [%] as function of length of shower (J. Huang)
- Do power law fit to obtain containment for arbitrary p and shower length

Electron Acceptance



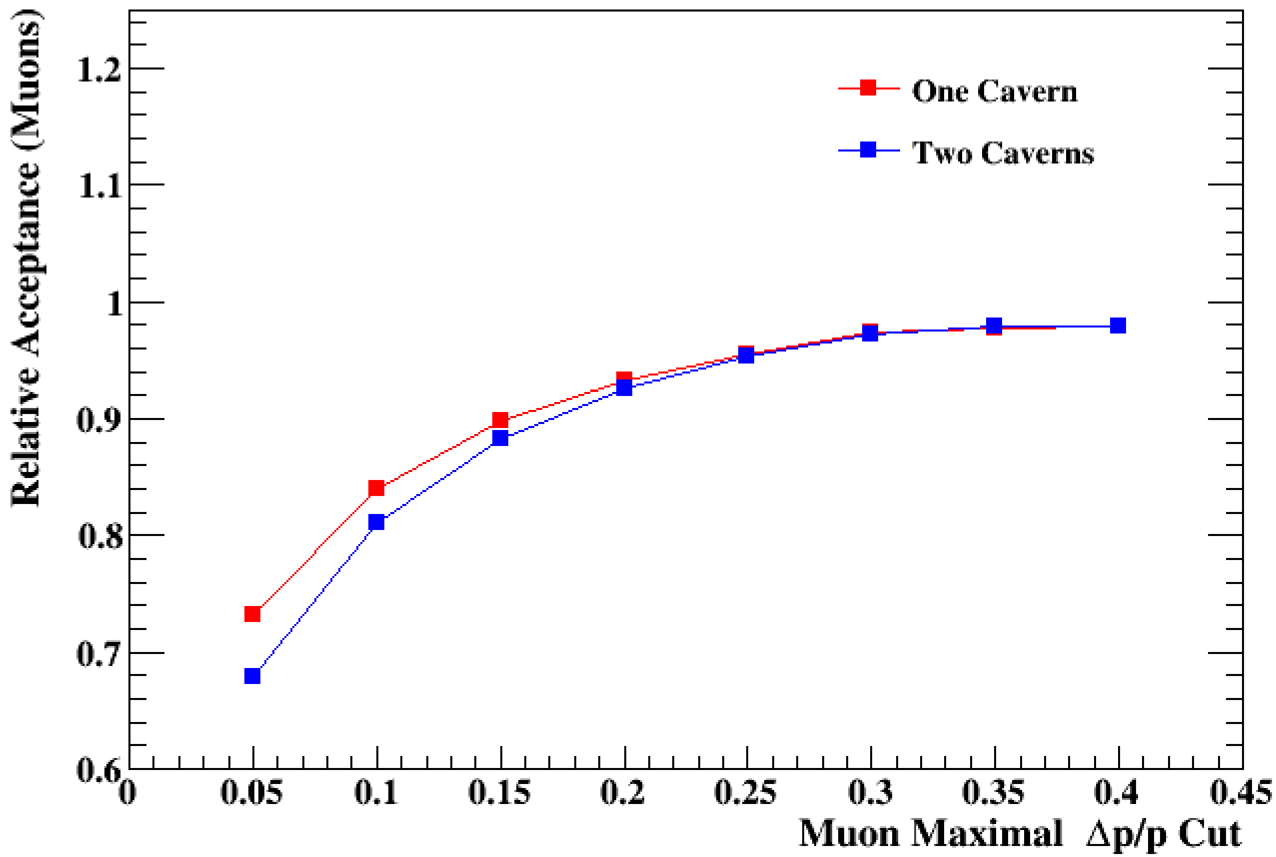
- Preliminarily: very little difference between cavern choices on electron acceptance → very little difference in physics sensitivity

Muon Δp/p from MCS



- Obtain MCS results from MicroBooNE study (L. Kalousis)
- Fit points (rational function for given p, then power law for p-dependence) to obtain Δp/p for arbitrary p and muon track length

Muon Acceptance



- Larger difference for muons (requiring cut on max allowed $\Delta p/p$)
- Left-most point (5% max res.) is ~100% contained muons

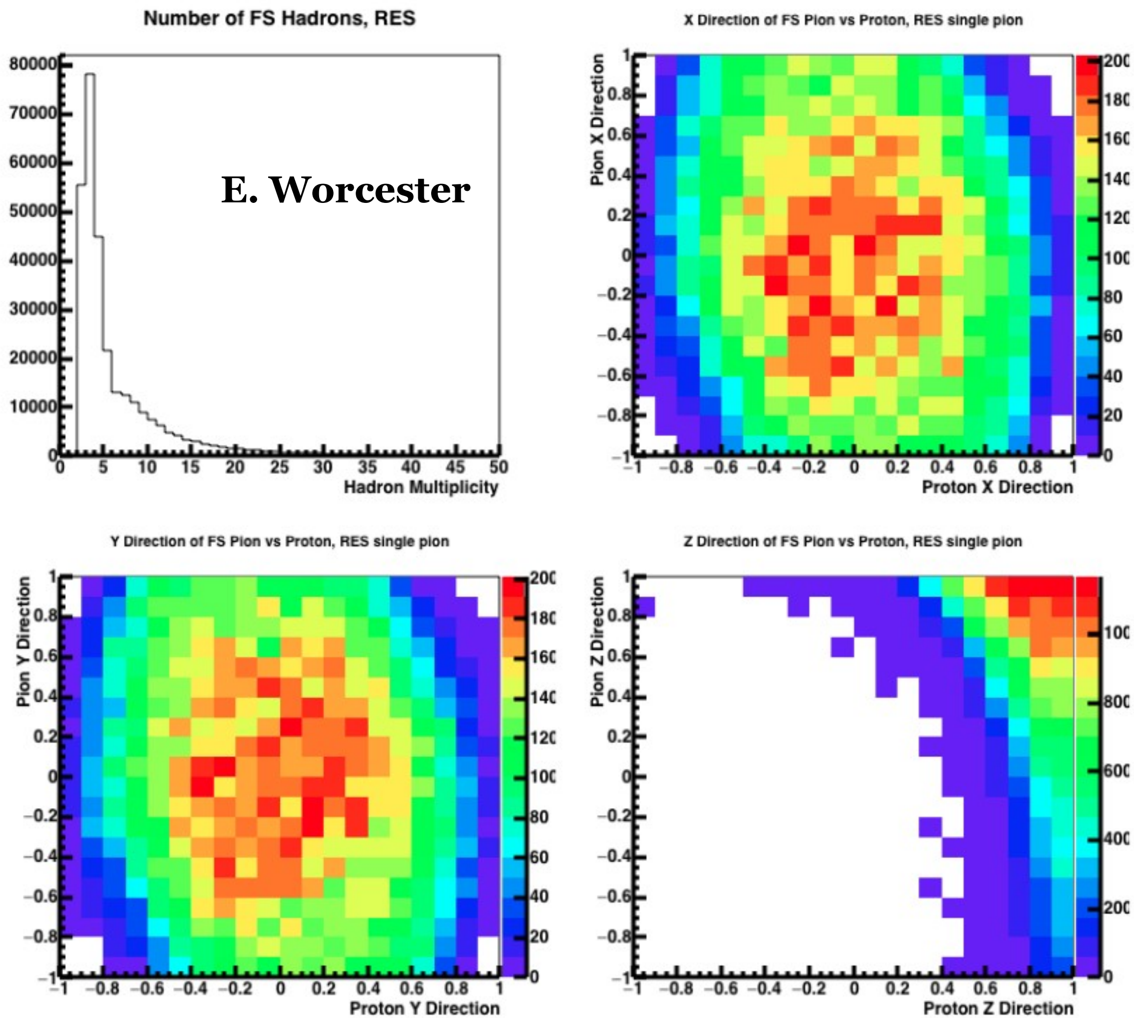
Planned Work

- New question: what dimensions should we use for the four 10-kt detectors?
    - Another question: how long do I have to wait for this question to change and void my studies? ;)
- Also take into consideration **hadron shower containment**
    - Important for neutrino energy reconstruction
    - Include **QEL**, **RES**, and **DIS** events
    - Include protons, pions, kaons (proton decay kinematics)
    - Don't forget topologies relevant for calibration! (e.g. neutral pions)
    - **Primary difficulty moving forward**
- Try to reduce use of full simulation as much as possible by lowering dimensionality of problem via parametrization
    - E.g. shower containment as function of angle to wall, distance of vertex from wall, and momentum
    - Use **Fast MC** when possible (Elizabeth helping on this front)

Fast MC Example

RES p+π final state

RES



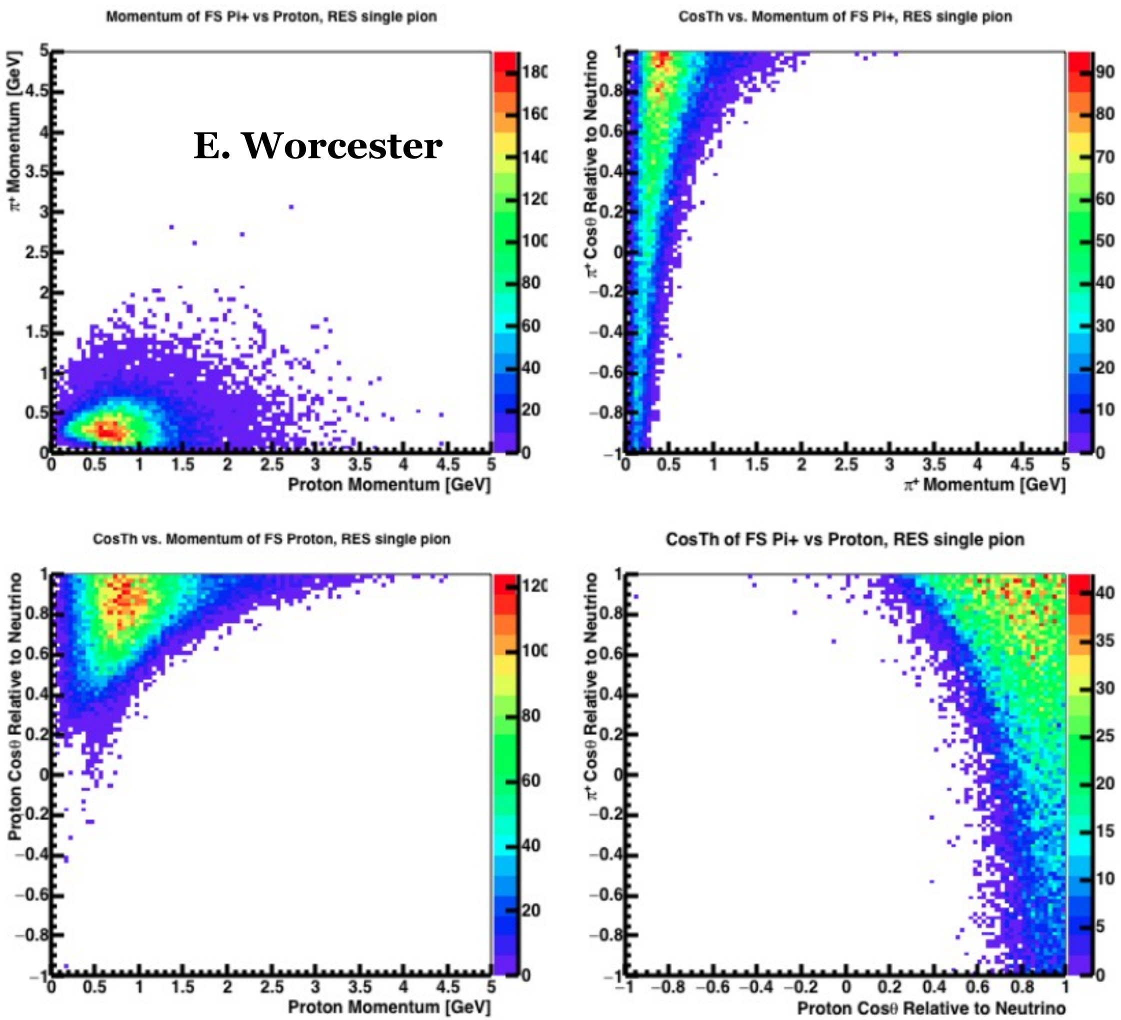
Notes:

- Most common case has >2 hadrons in final state
- Consider only 2 f.s. particles (proton & pion) for simplicity
- This will represent best case – if there are issues with containment, will need full simulation to study higher multiplicities

Fast MC Example (cont.)

RES p+π final state

RES: Single π^+



Notes:

- Most pion momenta < 0.5 GeV
- Most proton momenta < 1.0 GeV
- Restrict range of simulations to fairly low energies
- If assume no correlation between particle directions, easy to select pair of energies from top left and then an angle for each from upper right and lower left

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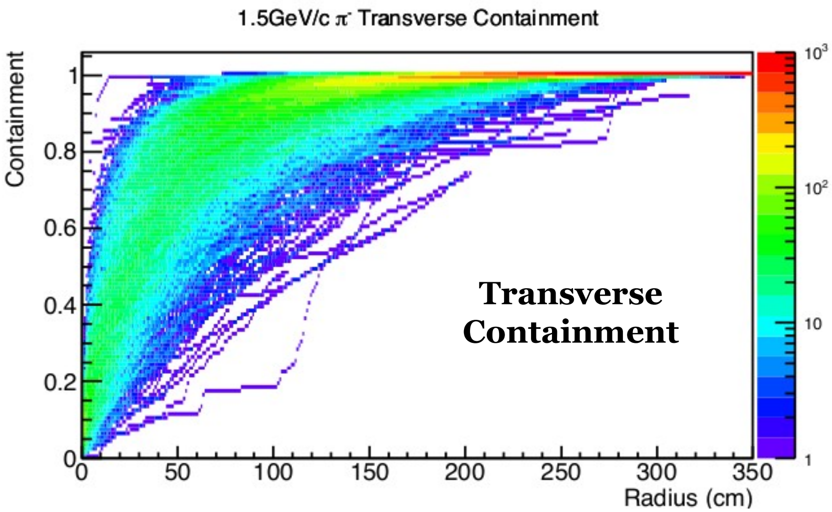
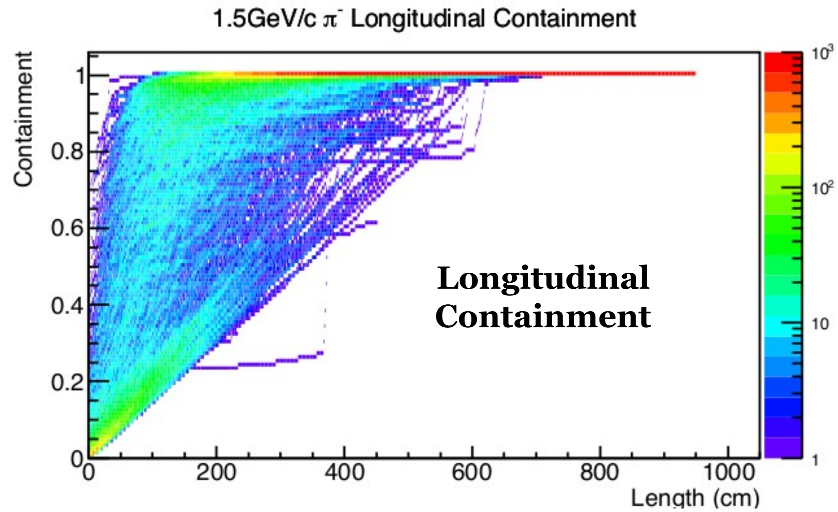
BACKUP SLIDES

Hadron Shower Profiles

CHARGED PIONS

J. Huang





PROTONS